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G92-1096 Understand Your Soil Test: pH-Excess Lime-Lime Needs

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Understand Your Soil Test: pH-Excess Lime-Lime Needs

The relationships among pH, soil type, and lime requirements are explained.

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Accurate soil tests can be an excellent management tool. Misuse of soil tests leads to increased production costs, yield losses, or both. The elements required by plants for proper growth have been determined by experimentation. Experience has shown that soils across Nebraska differ greatly in their capacity to supply these elements. The amount of each element supplied by a soil depends on several factors. Two important ones are: (1) the type of material from which the soil was formed, and (2) the treatment the soil has received since being placed under cultivation. Not all of a particular element in a soil is available to a plant. Thus, the soil test must be able to predict whether a soil contains sufficient amounts of available nutrient elements for a specific crop. This is one of a series of NebGuides designed to help crop producers interpret their soil test results.

pH

The acid and base levels of a soil solution are important because microorganisms and plants are responsive to their chemical environment. Three possible chemical reaction conditions for the soil solution are acidity, neutrality, and alkalinity. The reaction of the soil solution can be defined by an index using the concentration of hydrogen ions in the soil solution. This index is called the pH. A pH of 7 is neutral, pHs less than 7 are acid, and pHs greater than 7 denote a basic (alkaline) condition. Soil pH can be an indicator of the kind of nutrient problems to expect in a soil. Obviously the pH is not a "cure-all" analysis, but may indicate a possible problem, which may then be investigated with additional analysis. In mineral soils, pH is a general indicator of soil nutrient availability, presence of free lime (calcium carbonate), presence of excess sodium, and excess hydrogen. Almost all soils in Nebraska are mineral soils; thus, soil pH is a good indicator for possible nutrient problems. For example, sulfur is available from pH 5.5 to 8.5; boron, copper, and zinc are most readily available from pH 5 to 7; and iron and manganese are abundant below pH 5, but moderately available from pH 5 to 7. Iron chlorosis frequently occurs at pH above 7.7.

Factors Influencing pH

Initially, factors such as parent material, rainfall, and type of vegetation were dominant in determining the pH of Nebraska's soils. Under cultivation, however, organic acids from plant roots, repeated use of acid-forming fertilizers, plant removal, and replacement of calcium and magnesium by hydrogen eventually lowers the pH of topsoil. Most of the nitrogen and phosphorus fertilizers used today are acid forming. For example, about 1.5 pounds of lime is required to neutralize the effect of applying 1 pound of anhydrous ammonia to the soil. Most irrigation water in Nebraska contains substantial quantities of calcium and magnesium bicarbonates (lime) which help neutralize the acidifying effects. Thus, soils (without free lime) under production become increasingly acid unless lime is artificially applied or is present in the irrigation water. This means farmers need to frequently check soil pH to determine whether they are maintaining a proper soil acidity level.

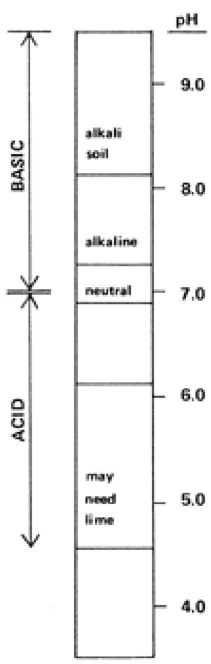


Figure 1

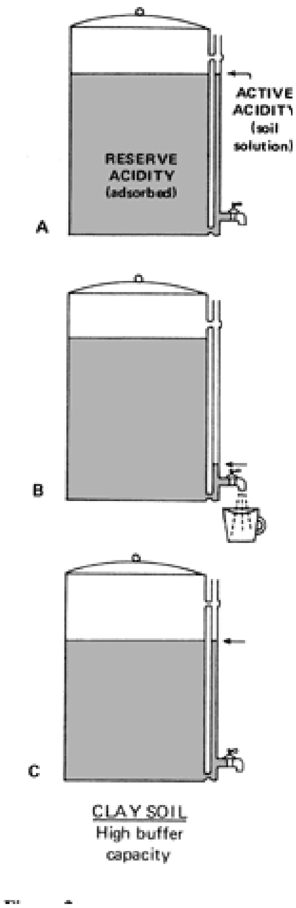
Lime Requirement

The standard pH measurement (*Figure 1*) is an estimate of the active hydrogen ions or acidity, that is, the hydrogen ions present in the soil solution. Hydrogen attached to the clay and organic matter is referred to as reserve acidity. The relationship between active and reserve acidity is not constant across soils, but is influenced primarily by type and amount of clay and organic matter content of the soil. As the clay and organic matter content of soil increases, the ratio of reserve to active acidity also increases. This relationship gives rise to the buffering capacity of the soil. Thus, the buffer capacity, or reserve of a sandy soil, is much less than that of a soil containing more clay such as a silt loam. Buffering, reserve, and active acidity may seem confusing, and in reality the soil is a complex system. However, the following analogy may give a simple explanation. Consider two full coffee urns (*Figure 2A*), one with a 50-cup capacity and the other 10-cup, both having the same size indicator tube and spigot.

Coffee in the indicator tube represents the activity acidity (measured by regular pH) and that in the urn represents the reserve acidity (measured by buffer pH). Let the large urn represent a clay soil high in organic matter while the small urn represents a sandy soil. Both urns have equal amounts of coffee in the indicator tube; i.e., the same active hydrogen, so the same pH. Now open the spigot and remove one cup of coffee from each urn (*Figure 2B*). Removing one cup of coffee from each urn could be equated to the addition of small amounts of limestone to an acid soil. Opening the spigot will cause the level of coffee in the indicator tube to drop below the level in the urn, but will return to almost the original level (clay soil) when the spigot is closed. The momentary drop in coffee in the indicator tube represents the initial increase in pH when lime is added (affects the active hydrogen), but reserve hydrogen (similar to coffee in the urn) soon equalizes the effect from the lime and the pH returns to essentially its original level (*clay soil, Figure 2C*). Thus, if the pH is 6.2 or lower, a buffer pH is run to measure the reserve acidity. The result of the buffer pH shows the amount of lime required to neutralize a major portion of the reserve acidity. The relative amounts of coffee in the two urns (*Figure 2C*) show why a sandy soil and a clay soil with the same pH result in different lime requirements. For example, the small addition of limestone (equivalent to removing one cup of coffee from each urn) reduced the total coffee (reserve acidity) by 10 percent in the small urn (sandy soil), but only 2 percent of the large urn (clay soil). In a similar manner, one ton of agricultural limestone will make a greater change in the pH of a sandy soil than of a clay soil.

Buffer pH vs. Soil pH

Figure 2A, B



Soil pH indicates the degree of acidity. Buffer pH (BpH) values are used to estimate how much lime is necessary to increase the soil pH to a more desirable level. Lime need cannot be determined on the basis of soil pH alone. The amount of clay and organic matter in the soil determine how much lime it takes to change the pH a given amount. There are two lime requirement tests used by soil testing laboratories serving Nebraska. Results from both tests are reported as buffer pH, but interpretation to pounds of lime is different. Table 1 shows the BpH for the Woodruff and SMP (Shoemaker, McLean and Pratt) tests for various amounts of lime required to bring the soil pH to 6.5. It can be seen from Table 1 that, except at BpH equal to 6.8, BpH is interpreted differently for the two tests. Also, the deeper lime is mixed with the soil, the more lime is needed.

Table 1. Amounts of lime needed to bring pH to 6.5 using 60% Effective Calcium Carbonate lime material according to Woodruff and SMP lime requirement tests.

Woodruff		**Buffer pH**	**SMP**	
6 2/3 inches*	**8 inches**		**6 2/3 inches**	**8 inches**
1,000 1b/A	1200 lb/A	6.9	— lb/A	— lb/A
2,000	2,400	6.8	2,000	2,400
3,000	3,600	6.7	3,500	4,200
4,000	4,800	6.6	4,800	5,800
5,000	6,000	6.5	6,000	7,400
6,000	7,200	6.4	7,800	9,400
7,000	8,400	6.3	9,200	11,000
8,000	9,600	6.2	10,700	12,800
9,000	10,800	6.1	12,000	14,400
10,000	12,000	6.0	13,500	16,200
***Depth of incorporation of lime in soil**				

Advantages and Disadvantages

The Woodruff and SMP methods will give about the same lime requirement on many soils. However, the SMP method is not sensitive enough for sandy soils having a lime requirement of less than 3,000 pounds per acre. This is the primary reason that the UNL Soil Testing Laboratory continues to use the Woodruff method. On the other hand, the SMP method measures buffered acidity due to exchangeable aluminum, whereas the Woodruff method does not. (A modified Woodruff method does, however.) Few, if any soils, in Nebraska contain significant amounts of exchangeable aluminum. Certain soils in southeast Kansas and various parts of the eastern cornbelt do, consequently a laboratory that expects to test these soils will most likely use the SMP method. Both methods are satisfactory on nonsandy soils in Nebraska. The Nebraska Experiment Station continues to look for a better method for sands. In the meantime the Woodruff method appears to be the most accurate for sandy soils.

Excess Lime, Alkali, and Salinity

Most Nebraska soils originally contained free lime and the underlying parent material from which the soils formed still does. Over a long period of time with sufficient rainfall, the free or excess lime is being removed from the top soil to depths of as much as 6 feet. However, on some upland slopes, erosion has occurred more rapidly than the down- ward movement of lime. Consequently, those surface soils still contain free lime. In river valleys, alluvial (water carried) deposits have continued, which cause some soils to contain free lime at the surface. Iron chlorosis in susceptible plants (soybeans and sorghum) is common on soils containing excess lime and selection of tolerant crops or varieties may be necessary. Frequently, on high lime soils, higher application rates of fertilizer (phosphorus and zinc) are necessary to provide adequate nutrients for crop growth. A pH above 7 indicates that the soil is alkaline. Soils containing free lime normally range from pH 7.3 to 8.3. Soils containing excess exchangeable sodium, called alkali, often have pH values up to 10.0. Saline soils are those that contain excessive amounts of sodium, calcium, magnesium, and potassium salts. Soils containing excess exchangeable sodium and salts are called saline-alkali. Additional tests are necessary to classify these soils for treatment. The tests needed are conductivity to determine the total salt content and exchangeable sodium to determine the extent of the alkali problem. Saline-alkali soils may or may not contain excess lime. Recommendations for managing these problem soils will be included with saline-alkali soil test reports.

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